above the exciting source is continually acting. The form of the decay curve in this case must only be regarded as empirical, as there appears to be no simple physical foundation for it.

This work was carried out in the Physical Laboratory of the University of Manchester, and I desire to express my gratitude to Prof. Rutherford for his valuable suggestions and his kind interest in the experiments.

Theory of the Luminosity produced in certain Substances by α-Rays.

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In the preceding paper, Mr. Marsden has examined the decay of the luminosity excited by α-rays in zinc sulphide, willemite, and barium platinocyanide, when subjected to an intense bombardment by α-particles. He has shown that the luminosity decreases with continued bombardment to a very small fraction of its initial value. For a given bombardment, the rate of decay of luminosity is about the same for zinc sulphide and willemite, but is especially rapid in barium platinocyanide. The action of the α-particles on phosphorescent zinc sulphide is of special interest and importance on account of the marked scintillations observed, and the fact that each α-particle under suitable conditions produces a visible scintillation. Mr. Marsden has brought out the essential fact that the actual number of scintillations observed for a constant source of α-rays changes very little with continued bombardment, but the brightness of the scintillations rapidly diminishes.

It is well known that the α-particles exert a marked dissociation effect in complex molecules on which they fall. For example, the α-rays from radium or its emanation, dissolved in water, dissociate the water molecules, producing hydrogen and oxygen at a rapid rate. I have shown elsewhere ('Radio-active Transformations,' p. 253), that the magnitude of this effect is in agreement with the view that each α-particle dissociates as many molecules of water as it produces ions in its path in air. The loss of energy of the α-particle in passing through a gas is mainly used up in producing ions in the gas. The laws of absorption of α-particles, which have been so carefully worked out by Bragg, show that no definite distinction as regards absorption can be drawn between a solid and a gas. It is reasonable to suppose that the α-particle produces ions in a solid as well as in a gas, and that the absorption of the α-particle is due mainly to the energy used up in this process. If the solid matter is composed of complex molecules, the latter will be dissociated by the α-particles. As Marsden has pointed out, pure zinc sulphide does not exhibit the scintillation effect, but this only appears in zinc sulphide to which certain impurities have been added. Since the amount of impurity present is of the order of 1 per cent., it is probable that only a small fraction of the total number of molecules give rise to the scintillation effect. These "active centres," as they will be called, will on the average be uniformly distributed among the inactive molecules.

In the theory of the decay of luminosity outlined in this paper, it is supposed that a scintillation results from the dissociation of a number of these active centres which lie in the path of the α-particle. Each active centre, when dissociated by an α-particle, emits light and is no longer effective in producing light when struck again by an α-particle. The effect of continued bombardment by α-particles is thus to destroy gradually the active centres. Since, probably, initially many thousands of these centres lie in the path of an α-particle, the effect of a continued bombardment will not cause a diminution in the number of scintillations, but a decrease in the intensity of each scintillation, for the intensity of a scintillation on an average will be proportional to the number of active centres remaining. This point of view is in agreement with the experimental results observed by Mr. Marsden.

Theory of Decay of Luminosity with Time.

Since the destruction of active centres is connected with their ionisation and consequent dissociation by the α-particles, it is necessary to consider how the ionisation varies within the layer of phosphorescent material. In the experiments of Marsden, a glass tube, coated inside with a layer of zinc sulphide or willemite, was exposed to the action of the α-rays from the emanation and its products. About three hours after the introduction of the emanation into the tube, the emanation and its products, Radium A, B, and C, are in equilibrium, and the same number of α-particles is emitted per second from the emanation, Radium A, and Radium C. The ranges of penetration of the α-particles from these three products are 4·33, 4·85, and 7·06 cm. respectively in air. Since the emanation was usually introduced at low pressure, the α-particles were not appreciably stopped by the gas in the tube. Each part of the surface of the phosphorescent material was exposed to a bombardment of α-particles falling equally from all directions. The thickness of phosphorescent matter was more than sufficient to stop the α-particles completely.

It was early observed that the total ionisation produced by a thin layer of active material from which α-particles were fired equally in all directions decreased approximately according to an exponential law when uniform screens of absorbing matter were placed over the active matter.

The variation of ionisation with distance under these conditions has been calculated by Bragg.* If R is the range of the α-particles in the material and D the thickness, then the value i/i_0 is given in the following table for different ratios of D/R. In this case i_0 represents the total ionisation due to the α-particles when no screen is interposed, and i the value of the total ionisation produced *after* traversing a distance D of the material.

D/R......	0	0·061	0·124	0·250	0·357	0·500	0·690	0·833	1·00
i/i_0	1·00	0·807	0·672	0·467	0·335	0·193	0·077	0·023	0

In this calculation, a correction is made for the variation of the ionisation due to an α-particle along its path. In the experimental case under consideration, it is required to find the variation of ionisation with distance for a thin layer of radio-active matter emitting three sets of α-particles, equal in number. Taking R as the range in the material of the α-particles from Radium C, the range of the α-particles from the emanation and Radium A are 0·613 R and 0·684 R respectively. Geiger† has shown that an α-particle from the emanation, Radium A, and Radium C produces $1{\cdot}74 \times 10^5$, $1{\cdot}87 \times 10^5$, $2{\cdot}37 \times 10^5$ ions respectively. By drawing a curve giving the variation of ionisation with distance traversed for each of the three sets of rays and adding them together, the variation of ionisation with distance for the three sets together can be deduced.

The results are collected in the following table:—

D/R......	0	0·05	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0
i/i_0	1·00	0·80	0·65	0·45	0·295	0·18	0·10	0·056	0·027	0·012	0·005	0
e^{-KD}......	1·00	0·80	0·64	0·41	0·26	0·165	0·105	0·067	0·042	0·027	0·017	0·011

It will be seen that the value i/i_0 falls off roughly according to an exponential law. This is brought out in the third column, where the values of e^{-KD} are plotted for a value $K = 4{\cdot}5/R$. With this value of K, the ionisation falls off to half value after the α-particles have traversed a distance 0·154 R. We can consequently assume, as a first approximation, that the ionisation decreases with distance traversed according to an exponential law. This assumption makes the final equations much more easily integrable.

Consider a layer of phosphorescent material of area one square centimetre and thickness dx at a depth x from the interior surface. Suppose P α-particles from the emanation and also from each of the α-ray products strike each square centimetre of surface per second. The number of ions produced in thickness dx is easily seen to be

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* Bragg, 'Phil. Mag.,' vol. 11, p. 754, 1906.

† Geiger, 'Roy. Soc. Proc.,' A, vol. 82, p. 486, 1909.

$$\mathrm{K} i_0 e^{-\mathrm{K}x} dx, \quad \text{where} \quad i_0 = \mathrm{P} \, . \, q,$$

where q is the sum of the number of ions produced by an α-particle from the three α-ray products.

The number of molecules of material (supposed mainly zinc sulphide) in thickness dx is Ndx, if N is the number of molecules of zinc sulphide per cubic centimetre. Consequently, the fraction of the total number of molecules ionised in the time dt is

$$\frac{\mathrm{K} i_0 e^{-\mathrm{K}x} \, . \, dx}{\mathrm{N} \, . \, dx} \, . \, dt = \frac{\mathrm{K} i_0 e^{-\mathrm{K}x}}{\mathrm{N}} \, . \, dt. \tag{1}$$

If the active centres be supposed to be of the same diameter as the inactive, so that the chance of being struck by an α-particle is the same, this must represent the fraction $-dn/n$ of the active molecules which are destroyed in the time dt, n being the number of active molecules present per unit volume.

Thus

$$\frac{dn}{n} = -\frac{\mathrm{K} i_0}{\mathrm{N}} e^{-\mathrm{K}x} \, . \, dt. \tag{2}$$

This equation will obviously hold if the active centres constitute only a small part of the total number present. If the active centres consist of molecular aggregates or small crystals of dimensions large compared with that of the zinc sulphide molecule, each of which is destroyed as a scintillation centre by the impact from an α-particle, it is obvious that their chance of being struck by an α-particle is much greater than if they were of molecular dimensions. In such a case it would be necessary to introduce a constant factor on the left-hand side of equation (2). We shall, however, first work out the theory on the simple hypothesis that the active and inactive molecules have the same chance of being struck by an α-particle. A comparison of theory with experiment will at once disclose whether such a correction is necessary.

Since, in the experiments of Mr. Marsden, the emanation in a sealed tube was used as a source of radiation, the radiation from it decays with time. If P_0 be the initial number of α-particles expelled per second from the emanation itself, the number P after a time t is given by $\mathrm{P} = \mathrm{P}_0 e^{-\lambda t}$, where λ is the constant of decay of the emanation. Under these conditions equation (2) becomes

$$\frac{dn}{n} = -\frac{i_0 \mathrm{K}}{\mathrm{N}} e^{-\mathrm{K}x} \, . \, e^{-\lambda t} \, . \, dt. \tag{3}$$

Putting $i_0 K/N = A$, and integrating between the limits t and 0,

$$\log_e \frac{n}{n_0} = -\frac{A}{\lambda}(1-e^{-\lambda t})\,e^{-Kx},$$

where n_0 is the value of n when $t = 0$. Thus

$$\frac{n}{n_0} = e^{-\frac{A}{\lambda}(1-e^{-\lambda t}).e^{-Kx}}. \tag{4}$$

Now the luminosity dI supplied by the layer dx is proportional to $-dn/dt$, and may be taken for simplicity as equal to $-dn/dt$. Then the total illumination I due to the whole layer of material acted on by α-particles is given by

$$I = \int_0^\infty -\frac{d}{dt}\;.\;dx.$$

Substituting the value of dn/dt from (3),

$$I = Ae^{-\lambda t}\int_0^\infty e^{-Kx}.\,e^{-\frac{A}{\lambda}(1-e^{-\lambda t}).e^{-Kx}}\,.\,dx.$$

Putting $e^{-Kx} = y$, this reduces to

$$I = \frac{A}{K}\,e^{-\lambda t}\int_1^0 e^{-\frac{A}{\lambda}(1-e^{-\lambda t})y}\,.\,dy$$

$$= \frac{\lambda e^{-\lambda t}}{K(1-e^{-\lambda t})}\left\{1-e^{-\frac{A}{\lambda}(1-e^{-\lambda t})}\right\}.$$

When $t = 0$, the value I_0 of the intensity of luminosity is given by

$$I_0 = A/K,$$

and

$$\frac{I}{I_0} = \frac{e^{-\lambda t}}{\frac{A}{\lambda}(1-e^{-\lambda t})}\left\{1-e^{-\frac{A}{\lambda}(1-e^{-\lambda t})}\right\}. \tag{5}$$

This gives the equation of decay of luminosity, and is seen to involve only one unknown constant A, since the decay constant λ of the emanation is known.

Simple Cases.

We can at once deduce from this equation the decay of luminosity for certain special cases of importance.

Case 1.—Suppose the bombardment is constant. In this case $\lambda = 0$. It is at once seen that

$$\frac{I}{I_0} = \frac{1}{At}(1-e^{-At}). \tag{6}$$

Case 2.—Suppose the layer of material is very thin compared with the range of the α-particles in it. In this case, the ionisation may be taken as sensibly constant and equal to Ki_0 through the thin layer.

Equation (3) in this case reduces to

$$\frac{dn}{n} = \frac{-Ki_0}{N} e^{-\lambda t} . dt,$$

and equation (4) becomes
$$\frac{n}{n_0} = e^{-\frac{A}{\lambda}(1-e^{-\lambda t})}.$$

From this it follows that I, which is equal to $-dn/dt$, is given by

$$\frac{I}{I_0} = e^{-\lambda t} . e^{-\frac{A}{\lambda}(1-e^{-\lambda t})}.$$

For a constant source of bombardment $I/I_0 = e^{-At}$, *i.e.* the luminosity decays according to an exponential law with the time. Such a result is to be anticipated from the general theory without calculation.

Case 3.—Suppose a screen is exposed to a narrow pencil of α-rays falling normally. In this case all the α-particles penetrate a distance equal to their range. Taking the ionisation as uniform along the path of the α-particles, it is clear that this case is similar to Case 2. With a decaying source of radiation

$$\frac{I}{I_0} = e^{-\lambda t} . e^{-\frac{A}{\lambda}(1-e^{-\lambda t})},$$

and for a constant source
$$I/I_0 = e^{-At}.$$

It is, however, well known that the ionisation in a gas due to a narrow pencil of α-rays increases at first, passes through a maximum, and then falls off rapidly to zero at the end of the range. The equations for I/I_0 deduced above consequently serve only as a first approximation. If required it would not be difficult to make a correction for the variation of ionisation along the path.

For the purpose of comparing theory with experiment it is convenient to express equation (3) in the form

$$\frac{I}{I_0} = \frac{e^{-\lambda t}}{B(1-e^{-\lambda t})} \{1-e^{-B(1-e^{-\lambda t})}\}. \tag{7}$$

The value of
$$B = \frac{A}{\lambda} = \frac{i_0 K}{N\lambda} = \frac{P_0 q . K}{N\lambda}. \tag{8}$$

The value of the constant B in different experiments is consequently proportional to the initial number P_0 of α-particles falling per second per square centimetre on the phosphorescent material.

It is of interest to observe that

$$B(1-e^{-\lambda t}) = \frac{qK}{N} \cdot P_0\left(\frac{1-e^{-\lambda t}}{\lambda}\right),$$

where the variable factor $\frac{P_0}{\lambda}(1-e^{-\lambda t})$ is equal to the total number of α-particles which have traversed the material.

It is obvious on this theory that the fraction of the active molecules destroyed by a bombardment depends only on the total number of α-particles which have struck the screen and not on their distribution with regard to time.

Comparison of Experiment with Theory.

In the experiment of Mr. Marsden, the bombardment of the screen by the α-particles increased for about three hours after the introduction of the emanation, due to the growth of the α-ray products Radium A and C. Systematic measurements were usually begun after the three hours' interval. For a comparison of experiment with theory it has been necessary to correct for the bombardment during this interval. This has been done by continuing the observed curve backwards, corresponding to an interval of two hours. This estimated correction is small for small bombardments, but becomes of more importance in the case of intense bombardments where the luminosity falls considerably in the course of a few hours.

The agreement between the experimental values and those deduced by taking a suitable value of the constant B in the equation

$$\frac{I}{I_0} = \frac{1}{B(1-e^{-\lambda t})}\{1-e^{-B(1-e^{-\lambda t})}\}$$

is shown in the following tables. The first column gives the time in hours calculated from one hour after the introduction of the emanation; the second column the value of $e^{-\lambda t}$ for the emanation, taking the half period as 3·85 days.

It will be seen that there is a substantial agreement between theory and experiment for both zinc sulphide and willemite over a considerable range of intensity of bombardment. Taking into account the approximate nature of some of the assumptions and the experimental difficulty of accurate measurement of the weak luminosity, the agreement between the calculated and observed numbers is as close as could be expected. In the simple theory no account has been taken of the effect of the β-rays on the material, within or outside the range of penetration of the α-particles, though it is probable that the luminosity due to this cause becomes important when most of the active centres in the surface layer have been destroyed. In one experiment

Zinc Sulphide.

Time in hours.	$e^{-\lambda t}$.	A. Bombardment, 4×10^7 α-particles per sec. per sq. cm.		B. Bombardment, 2×10^8 α-particles per sec. per sq. cm.	
		Observed value, I/I_0.	Calculated value, I/I_0. B = 3.	Observed value, I/I_0.	Calculated value, I/I_0. B = 12.
0	1·00	1·00	1·00	1·00	1·00
5	0·963	0·90	0·86	0·78	0·77
10	0·928	0·82	0·83	0·63	0·61
20	0·861	0·69	0·70	0·44	0·42
30	0·798	0·59	0·60	0·315	0·30
40	0·741	0·51	0·52	0·22	0·23
50	0·687	0·45	0·445	0·185	0·18
60	0·638	0·395	0·39	0·15	0·15
80	0·549	0·31	0·30	0·10	0·10
100	0·472	0·25	0·24	0·06	0·08
120	0·407	0·22	0·19	0·045	0·06

Willemite.

Time in hours.	$e^{-\lambda t}$.	A. Bombardment, 6×10^7 α-particles per sec. per sq. cm.		B. Bombardment, $1{\cdot}3 \times 10^8$ α-particles per sec. per sq. cm.	
		Observed value, I/I_0.	Calculated value, I/I_0. B = 1·4.	Observed value, I/I_0.	Calculated value, I/I_0. B = 3·1.
0	1·00	1·00	1·00	1·00	1·00
5	0·963	0·92	0·93	0·905	0·91
10	0·928	0·86	0·88	0·825	0·83
20	0·861	0·76	0·78	0·69	0·695
30	0·798	0·68	0·69	0·59	0·585
40	0·741	0·615	0·62	0·51	0·50
50	0·687	0·555	0·56	0·44	0·44
60	0·638	0·505	0·50	0·39	0·38
80	0·549	0·41	0·405	0·31	0·29
100	0·472	0·34	0·335	0·255	0·23
120	0·407	0·28	0·27	0·215	0·19
140	0·349	—	—	0·18	0·15

of Mr. Marsden where the bombardment was very intense (10^9 α-particles per square centimetre per second), the agreement between theory and experiment is not so good. This is not unexpected, for the bombardment was so intense that the luminosity increased little, if any, after the introduction of the emanation. This shows that a considerable fraction of the active centres in the surface layers had been destroyed before the emanation was in equilibrium with its products and regular measurements begun.

It will be noted that on this theory the active centres in the surface layer where the ionisation is most intense are destroyed far more rapidly that those in the deeper layers. In consequence of this, the luminosity with continued bombardment is supplied more and more from the deeper layers of the material.

Value of the Constant B.—The value of the constant B in the formula can be calculated on certain assumptions. Its value is given by

$$B = \frac{P_0 q K}{\lambda N} = \frac{4 \cdot 5\, P_0 q}{\lambda N R},$$

since we have already shown earlier that $K = 4 \cdot 5/R$, where R is the range of the α-particle from Radium C in the material under investigation.

It is known that the ionisation due to an α-particle is approximately the same for all simple gases, but increases somewhat for complex gases and vapours. In the absence of definite information, it will be assumed for the purposes of calculation that the number of ions produced in the solid material is equal to the number of ions produced in a simple gas, for example, in air. Taking the values of the ionisation found by Geiger (*loc. cit.*) for an α-particle from the emanation, Radium A and C, the value of

$$q = (1 \cdot 74 + 1 \cdot 87 + 2 \cdot 37)\, 10^5 = 6 \times 10^5.$$

Taking the half period of the emanation as 3·85 days, $\lambda = 1/481000\ (\text{sec.})^{-1}$. The values of R and N vary for each substance, but can be simply determined. Taking the density of zinc sulphide (ZnS), willemite (Zn_2SiO_4), barium-platinocyanide ($BaPt(CN)_4$) as equal to four, it can easily be shown that the range of the α-particle from Radium C is

For zinc sulphide	$R = 3 \cdot 7 \times 10^{-3}$ cm.
„ willemite	$R = 3 \cdot 0 \times 10^{-3}$ „
„ barium platinocyanide ...	$R = 4 \cdot 2 \times 10^{-3}$ „

The range for each substance is calculated from Bragg's rule that the stopping power of a complex molecule is very approximately proportional to the sum of the square roots of the atomic weights of the constituent atoms. The range of the α-particle from Radium C in aluminium (0·004 cm.) is taken as a basis of comparison. Taking the charge on a hydrogen atom as $4 \cdot 65 \times 10^{-10}$ electrostatic unit, it can readily be calculated that the value of N, the number of molecules per unit volume, is

For zinc sulphide	$2 \cdot 57 \times 10^{22}$
„ willemite	$1 \cdot 12 \times 10^{22}$
„ barium platinocyanide	$5 \cdot 7 \times 10^{21}$

The value of the constant B is independent of the density of the material, since the value of N varies directly, and the value of R varies inversely as the density. In a similar way, the value of the charge for a hydrogen atom is not involved, for q and N vary inversely as the value of this quantity. Collecting results, it is seen that

For zinc sulphide .... $B = 1{\cdot}37 \times 10^{-8} . P_0$
„ willemite .... $B = 3{\cdot}9 \times 10^{-8} . P_0$
„ barium platinocyanide...... $B = 5{\cdot}4 \times 10^{-8} . P_0$

P_0 here represents the number of α-particles per second per square centimetre from the emanation alone, or one-third the actual bombardment when in equilibrium with its products. The calculated and observed values of B are shown in the following table:—

	$3P_0$.	B (calc.).	B (obs.).	$\frac{B\ (obs.)}{B\ (calc.)}$.
Willemite	6×10^7	0·78	1·4	1·8
	$1{\cdot}3 \times 10^8$	1·7	3·1	1·8
Zinc sulphide	4×10^7	0·18	3·0	$\left.\begin{matrix}17\\13\end{matrix}\right\}15$
	2×10^8	0·9	12·0	
Barium platinocyanide	About $1{\cdot}5 \times 10^7$	0·3	1400	4700

The decay of the luminosity of barium platinocyanide takes place much more rapidly than for willemite and zinc sulphide. The numbers for this substance given in the above table were deduced from data obtained by Marsden. A rod coated with the material was inserted through mercury in a space containing emanation in equilibrium. With a bombardment of $1{\cdot}5 \times 10^7$ α-particles per square centimetre per second, the luminosity of the barium platinocyanide decayed to half value in 8 minutes.

The calculated values of B given in the above table are deduced on the assumption that the same number of ions is produced in the material as in air, and that the active centre has the same chance of being struck by an α-particle as a molecule of the material. The latter condition implies that the active centre is of the same dimensions as the molecule.

In interpreting the relation between the observed and calculated values of B, there are two points of view that may be considered. In the first place, t may be supposed that the active centre is a molecular aggregate of greater dimensions than the molecule, and has, consequently, a greater chance than a molecule of being struck by an α-particle. If we suppose that the chance of being struck is proportional to the cross-section of the aggregate, it is seen from the above table that for willemite, zinc sulphide, and barium platinocyanide, the active centres have cross-sections about 2, 15, and 5000 times that of the corresponding molecules. On such a point of view, the number of active centres must be small compared with the number of inactive molecules.

In the second place, it may be supposed that in substances like zinc sulphide, where the molecular arrangements are very easily disturbed by the action of light or other weak stimuli, the region of dissociation of an α-particle is not confined to the molecules and active centres directly in its path, but extends some distance from it. In such a case, the dissociation of the neighbouring active centres is to be ascribed to the effect of the secondary radiations set up by the α-particle in the molecules in its direct path. On this theory, the region of disturbance is small for willemite, but in zinc sulphide is sufficiently large to cause about fifteen active centres to be dissociated for one directly struck by an α-particle. In barium platinocyanide the active centres are so numerous or so unstable that the ratio is nearly 5000.

This point of view of the action of the α-particle may be expressed in another way without taking into consideration the ionisation produced by the α-particle. Suppose that an α-particle, in its passage through the material, destroys all the active centres in a cylinder of average cross-section A and of length equal to its range in the material. For simplicity, take the case of a very thin layer of the material on which P α-particles fall per second per square centimetre. The fraction of the volume destroyed in the first second is PA. It is readily seen from equation (2) that, under the conditions specified, $\mathrm{PA} = -dn/n = \mathrm{A} = \mathrm{B}\lambda$, where B is the constant deduced experimentally for an initial bombardment P, and $\lambda = 1/481000$ is the constant of the radium emanation. If d be the diameter of the cylinder of action of the α-particle, $d = \sqrt{(4\mathrm{B}\lambda/\pi\mathrm{P})}$.

We shall now calculate the value of d for special examples—

Zinc sulphide.............. $\mathrm{P} = 2 \times 10^8$, $\mathrm{B} = 12$, $d = 1{\cdot}3 \times 10^{-7}$ cm.
Willemite .... $\mathrm{P} = 1{\cdot}3 \times 10^8$, $\mathrm{B} = 3{\cdot}1$, $d = 2{\cdot}5 \times 10^{-7}$ „
Barium platinocyanide... $\mathrm{P} = 1{\cdot}5 \times 10^7$, $\mathrm{B} = 1400$, $d = 1{\cdot}6 \times 10^{-5}$ „

It is seen that the diameter of the cylinder of action of each α-particle is, for willemite and zinc sulphide, somewhat greater than the diameter of the sphere of action of the molecule. The diameter of the latter for ordinary gaseous molecules is calculated by Meyer ('Kinetic Theory of Gases') to be between 2×10^{-8} and 10^{-7} cm. The value of d for barium platinocyanide is undoubtedly very large compared with the diameter of a molecule.

On both points of view, it must be supposed that the luminosity due to α-rays accompanies the dissociation of the active centres and cannot be ascribed to the recombination of the dissociated parts, for there is an undoubted chemical alteration of the material due to continued bombardment.

Whatever point of view is taken, it is clear that for willemite and zinc sulphide the active centres have dimensions comparable with a molecule. This excludes the suggestion put forward at one time that the scintillations of zinc sulphide due to α-particles were a consequence of the mechanical cleavage of small crystals.

I am indebted to Mr. Marsden for the use of the data obtained by him, and for his assistance in calculation of the decay curves.

Measurements of the Absolute Indices of Refraction in Strained Glass.

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1. In June, 1907, the author described* a method by which the double-refraction in strained glass could be measured by observing the deviation of a ray of light passing through a slab of glass under flexure.

If a slab or beam of glass of rectangular cross-section be bent in a vertical plane under a bending moment M, and if a plane wave be transmitted through the glass in a direction perpendicular to the plane of flexure, the light is broken up into two components, one polarised horizontally (*i.e.* perpendicular to the cross-section and along the line of stress) and the other vertically.

It was shown in the paper referred to that the variation in the index of refraction of the glass, due to the stress, produces in the vertically polarised ray an upwards deflection

$$\theta_1 = C_1 M\tau/I \text{ radians,} \tag{1}$$

and in the horizontally polarised ray a deflection

$$\theta_2 = C_2 M\tau/I \text{ radians,} \tag{2}$$

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* 'Roy. Soc. Proc.,' A, vol. 79, pp. 440—442.